Journal of Genetic and Environment Conservation (JOGEC)
www.jogec.com

Print ISSN: 3007-4509 Online ISSN: 3007-4517

Morphometric parameters analysis of white and brown Domyati ducks (Local Mallard in Egypt)

Abdel-Tawab, M[1]., A. Makram[2]*, Shahrazad M.J. Al-Shadeedi[3], I. El-Wardaney[1], A. Zein El-Dien[1], A.H. El- Attar[1] and A.M. Abdelmoniem[1]

[1]Poultry Production Department, Faculty of Agriculture, Ain Shams University, Egypt and [2]Poultry Production Department, Faculty of Agriculture, Fayoum University, Egypt. [3]College of Veterinary Medicine, University of Baghdad, Iraq.

***Correspondence:** Am150@Fayoum.edu.eg

Received: April 5th 2025
Accepted: May 7th 2025
Published: May 24th 2025
DOI: https://doi.org/10.63799/jgec.13.1.5

OPEN ACCESS

ABSTRACT

Morphometric traits or body conformation traits also called linear body measurements are important in predicting marketing body weight especially for commercial breeders and producers. The total number of reared Domyati ducklings are 168 hatched, at marketing age (8 wks.) 44 brown and 14 white Domyati ducks were used to estimate the body weight and body measurements such as shank length (ShL), keel length (KL), body circumference (BC), breast length (BrL), breast width (BrW), beak width (BL), and body length (BL). Our results showed that there is no significant difference between both white and brown Domyati ducks for body measurements. There was high positive correlation among body weight and body measurements on both white and brown Domyati ducks, especially in brown line. With respect to regression analysis, the R2 was higher for body measurements of white Domyati duck, while it was lower on brown Domyati ducks. The correlation was positive in both phenotypes but was higher in the Domyati brown duck, and there was a clear difference in the regression analysis between the two phenotypes in of Domyati ducks. The R2 was lower in brown Domyati duck, while the R2 was higher on white Domyati duck for most studied body measurements. In conclusion, there was a feather color effect on linear regression models and correlation among body weight and body measurements.

Keywords: Feather color, Body measurements, Pearson correlation, Linear & Nonlinear Regression, Native Mallard duck, Domyati duck.

Introduction

Domyati duck (*Anas platyrhynchos*) is one of the local strains in Egypt and similar in its phenotypic characters to standard Mallard Duck breed, which is distinguished by the quality of its meat and egg production, making it a desirable breed for many consumers in Egypt (Makram 2015; 2016; Alsaffar et al., 2024). Local strains are generally characterized by their high immunity and adaptation to the climatic conditions of the country in which they live. They are also often raised in villages and small projects, which they are sought after for local consumption. Local breeds often vary in appearance, such as feather color or body proportions, this variation occurs within the same breed. Therefore, improving local breeds begins by characterizing their phenotypic and productive performance (Galal et al., 2011; Makram, 2015 and 2016; Makram et al., 2024). The livestock characteristics may be observed through both quantitative and qualitative features, with the quantitative attribute being connected to the animal's economic properties. However qualitative traits like body shape and feather color, may be associated with quantitative traits (Ismoyowati et al.

2017). Teguia et al., (2008) reported that in Muscovy ducks the relationship between live body measurements and carcass components depended on the correlation between body weight and chest circumference, keel length and thigh length. Yakubu and Ugbo (2011) compared morphological variations between two duck populations reared in different areas in Nigeria for body length and breast circumference at 45 weeks of age. Saatci et al. (2005) indicate that the feather color in geese play a significant role in determining hatching weight of goslings. There are few studies focused on the effect of feather color on growth performance in waterfowls and the little study found that no effect of feather color on carcass traits in geese (Saatci et al., 2009, Sarıca et al., 2015, Kırmızıbayrak and Boğa, 2018). Abdel-Tawab et al. (2025) reported that there is a significant difference between white and brown Domyati ducks for some studied carcass traits.

Materials and Methods

A total of 168 healthy Domyati ducklings with high vitality were hatched and reared under identical environmental, management, and hygienic conditions from day one until the conclusion of the experiment. The ducklings were categorized into two groups based on feather coloration: Brown-feathered (Br-F) comprising 91% of the population and White-feathered (Wt-F) representing the remaining 9% (Figure 1).

Figure (1): Photo of brown and white Domyati duck (Egyptian Mallard).

At 8 weeks of age 44 (22 male+ 22 female) brown Domyati and 14 (7 male + 7 female) white Domyati birds were used for measuring body measurements in millimeter as follows:

1. Shank Length was measured as the length of the tibiotarsus (from the top of the hock joint) to the foot pad with a digital caliper.
2. Keel Length: measured for each duck individually by a digital caliper.
3. The body circumference is taken from the site under the wings to the edge of sternum.
4. Body Length: a longitude body beginning from beak to termination bird foot.
5. Breast Length: The distance between the first dorsal vertebra and sternum.
6. Breast Width: The distance between right and left glenoid cavity.
7. Beak Length: The distance between the tip of the bill and rear end of the beak.
8. Beak Width: The width of the beak from the center of the upper beak through the distance from the right side to the left side.

Statistical Analyses: Data is concerned with body measurements, using the General Linear Model (GLM) procedure of (SAS, 2013) according to the following model:

$Y_{ij} = \mu + F_i + e_{ij}$

Where: Y_{ij}=Trait measured, μ=Overall means, F=Feather color effect & e_{ij}=Experimental error

Pearson Correlation Analysis: Dataset contains two continuous variables (X and Y). Statistical software which is used for visualization correlation matrix by (CORRPLOT package) is (R-Studio, 2024). Pearson correlation measures the linear relationship between two continuous variables according to the following model:

$r=[\sum(X_i-\bar{X}) (Y_i-\bar{Y})] / [\sqrt{(\sum(X_i-\bar{X})2\sum(Y_i-\bar{Y})2)}]$

Where: r is the Pearson correlation coefficient, X_i and Y_i are individual data points., $\bar{X}$ and $\bar{Y}$ are the means of X and Y, respectively.

The correlation coefficient (r) was calculated to measure the strength and direction of the linear relationship. The significance of the correlation was tested using a t-test, where the null hypothesis is that there is no correlation (r=0). The p-value was used to determine the statistical significance of the correlation.

Linear and Nonlinear Regression Analysis: Dataset containing the dependent variable (Y) and independent variable (X). Statistical software which is used for regression analysis is (SPSS, 2011).

Linear Regression: Linear regression model shows the relationship between the dependent variable (Y) and the independent variable (X) using a linear equation model:

$Y=\beta_0+\beta_1X+\epsilon$

Where: Y is the dependent variable (body measurements), X is the independent variable (live body weight), β0 is the intercept, β1 is the slope coefficient & ϵ is the error term.

Nonlinear Regressions:

Quadratic Regression: Using a second-degree polynomial using the following equation model:

Y=β0+β1X+β2X2+ϵ

Where: X2 is the square of the independent variable.

Cubic Regression: Using a third-degree polynomial using the following equation model:

Y=β0+β1X+β2X2+β3X3+ϵ

Where: X3 is the cube of the independent variable.

Logarithmic Regression: Using the following equation model:

Y=β0+β1ln(X)+ϵ

Where: ln(X) is the natural logarithm of the independent variable.

For each model, the coefficients (β0, β1, β2, β3) were estimated using the least squares method. The goodness of fit for each model was assessed using the coefficient of determination (R^2) and the p-value for each coefficient. Residual analysis was conducted to check the assumptions of normality, homoscedasticity, and independence of errors.

Results and Discussion

Body Measurements: All measured traits (shank length, keel length, body circumference, breast dimensions, beak size, and body length) showed no statistically significant differences ($p > 0.05$) between Brown (Br-F) and White (Wt-F) Domyati ducks in Table (1).

Genetic Homogeneity: Feather color variation (Br-F vs. Wt-F) may not be linked to structural growth traits in Domyati ducks, suggesting these loci are independent of genes controlling body morphology (e.g., MC1R for plumage color vs. IGF1 for growth) (Yakubu et al., 2015; Makram et al., 2021).

Environmental Uniformity: Strictly controlled rearing conditions (diet, hygiene, management) likely minimized phenotypic plasticity, masking potential minor genetic effects (Galal et al., 2011; Teguia et al., 2008).

Slightly higher (but non-significant) values in Wt-F ducks for keel length, body circumference, and breast dimensions might reflect sampling variability because of small sample size in the Wt-F group (9%) could inflate standard errors (± values). Near-identical beak length/width ($p > 0.05$) aligns with findings that beak morphology is conserved across duck breeds unless under strong selective pressure (Ismoyowati et al., 2017).

In Mallards, wild-type plumage (brown) males exhibit larger body sizes than females due to sexual dimorphism, but no significant size differences exist between natural color morphs. This aligns with our Domyati duck findings where brown and white feather variants showed no statistically significant differences in body measurements (Guay and Tracey, 2009).

Mallard duck studies demonstrate that beak length and width correlate strongly with foraging efficiency but show low heritability, indicating these traits are more influenced by environmental factors than genetics. This parallels our Domyati results where beak dimensions showed no significant variation between brown and white-feathered ducks (Olsen et al., 2021).

Research on Mallards indicates that controlled rearing conditions (uniform diet, housing, and management) significantly reduce phenotypic variance, often masking potential genetic differences between groups. This supports our results where standardized rearing conditions likely minimized observable differences between feather color groups (Heath et al., 2020).

Wild Mallards exhibit pronounced sexual size dimorphism, with males being 10-15% larger than females in body mass and linear measurements. This contrasts with our Domyati data where sexes were presumably balanced across groups, resulting in no significant size differences between color variants (Baldassarre, 2014).

Pearson correlation coefficients: Pearson correlation coefficients were calculated between body weight (BW) and various body measurements in two genetic lines of Domyati ducks: brown and white. Correlation values provide insights into which traits are most associated with body weight, potentially helping to improve selection criteria in breeding programs.

In the brown line: The highest correlation with body weight is breast length ($r = 0.92$), followed closely by shank length ($r = 0.94$), body length ($r = 0.97$), and body circumference ($r = 0.95$). All body measurements show strong positive correlations with body weight, suggesting a consistent growth pattern. Notably, breast width ($r = 0.89$) and beak measurements ($r = 0.92–0.95$) are also positively associated. This strong set of correlations suggests that skeletal and muscle development (e.g., keel, breast, shank) are good predictors of BW in the brown line.

Table (1): Effect of Feather color (F) (Brown and white) on Body Measurements of Domyati duck

Traits	Domyati Duck Lines		Probability
	Brown	White	
Shank length (mm.)	82.05±0.60	82.17±1.40	NS
Keel length (mm.)	123.37±0.79	126.5±2.61	NS
Body Circum. (mm.)	39.32 ±0.25	40.08±0.31	NS
Breast length (mm.)	174.75±2.82	177.17±5.12	NS
Breast width (mm.)	87.09±0.74	88.33±1.77	NS
Beak length (mm.)	63.71±0.48	64.17±1.13	NS
Beak width (mm.)	26.86±0.16	26.58±0.38	NS
Body length (mm.)	77.31±0.43	78.29±1.08	NS

NS = Non-significant, (‘Brown = 91%” and “White = 9%” from total population phenotypes).

In the white line: The highest correlation with body weight is keel length (r = 0.95), followed by beak width (r = 0.91) and shank length (r = 0.92). While most correlations remain strong, a noticeable drop is seen with breast width (r = 0.86) and especially body length (r = 0.92). Body circumference (r = 0.85) also shows a relatively lower correlation than in the brown line. This suggests that while body weight in white ducks is still associated with body measurements, there may be more variability in fat deposition and skeletal conformation. The high positive correlations, especially in the brown line, indicate that linear body measurements can serve as reliable indicators of growth and productivity in ducks. Traits like keel length, shank length, and breast dimensions are especially useful in estimating body weight.

These results align with previous studies showing that morphometric traits are useful in indirect selection for body weight, particularly in indigenous duck breeds (Yakubu et al., 2011; Ibe, 1989). Moreover, the differences in correlation strengths between the brown and white lines may reflect underlying genetic variability, which should be considered in selection programs (Figures 2 and 3).

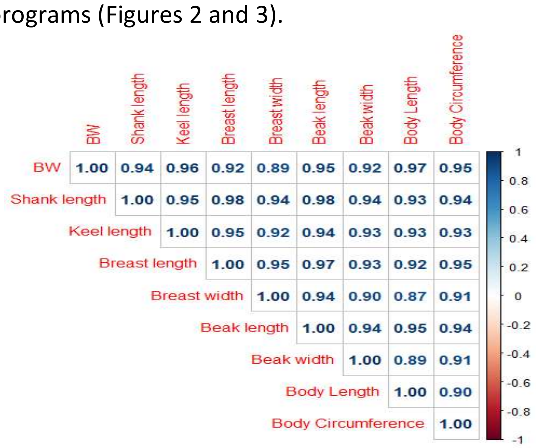


Figure (2): The correlation between body weight and body measurements of brown Domyati duck

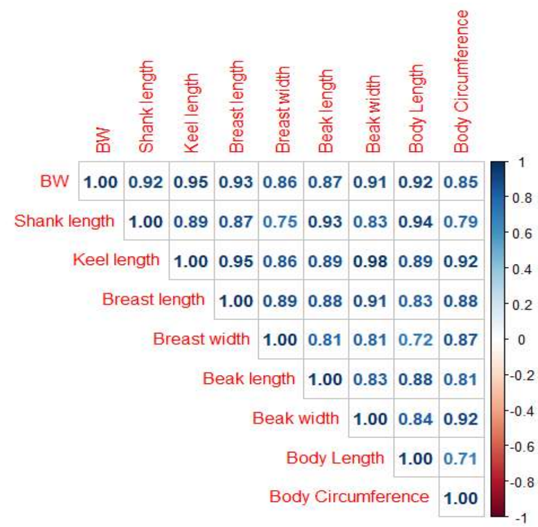


Figure (3): The correlation between body weight and body measurements of white Domyati duck

Regression analysis: Regression analysis was performed on data set based on feather color in Table (2) and Figures (4, 5, 6, 7, 8, 9, 10 and 11). Linear regression analysis was conducted and observed in table 2 to evaluate the effect of various body measurements on body weight (BW) in two lines of Domyati ducks: the brown feather line and the white feather line. In each case, BW was considered the dependent variable (Y), while traits such as shank length, keel length, breast length and width, beak length and width, body length, and body circumference were treated as independent variables (X).

Regression analysis: Regression analysis was performed on data set based on feather color in Table (2) and Figures (4, 5, 6, 7, 8, 9, 10 and 11). Linear regression analysis was conducted and observed in table 2 to evaluate the effect of various body measurements on body weight (BW) in two lines of Domyati ducks: the brown feather line and the white feather line. In each case, BW was considered the

dependent variable (Y), while traits such as shank length, keel length, breast length and width, beak length and width, body length, and body circumference were treated as independent variables (X).

In the brown-feathered ducks, the most significant predictors of body weight were keel length, beak length, and body length. Keel length had a strong and statistically significant effect on body weight, with an R^2 value of 0.521 ($p < 0.001$), indicating that this single trait alone explained more than 52% of the variation in body weight. Similarly, beak length showed a strong relationship with BW ($R^2 = 0.493$, $p < 0.001$), highlighting its predictive importance. Body length also contributed meaningfully to the prediction model, with an R^2 value of 0.357 ($p < 0.001$).

Shank length showed a relatively low R^2 value (0.095) with a p-value of 0.042, indicating a weak but statistically marginal influence on body weight. Breast width and body circumference showed very low R^2 values (0.026 and 0.001, respectively), and neither was statistically significant ($p = 0.3$ and $p = 0.837$). Beak width also showed no significant relationship with BW ($R^2 = 0.135$, $p = 0.455$).

Although breast length showed an R^2 value of 0.84 with a highly significant p-value (< 0.001), this result seems inconsistent with the corresponding regression coefficients (which were near zero). This might suggest a reporting error or an artifact in the model fitting process and should be verified with the raw data.

In contrast, the white-feathered ducks displayed consistently high predictive power across all morphometric traits. Keel length again emerged as the strongest individual predictor of BW, with an R^2 of 0.911 ($p < 0.001$), closely followed by breast length ($R^2 = 0.863$), body length ($R^2 = 0.855$), and shank length ($R^2 = 0.839$). All these traits showed very high statistical significance ($p < 0.001$), suggesting a strong and reliable relationship with body weight.

Table (2): Regression analysis values, R square and P values of body morphometrics for brown and white Domyati duck lines

Traits (Y)	LBW (X)				p-value
	b1	b2	b3	R^2	
Brown Feather line					
Shank length	-248	-0.028	-1.509	0.095	0.042
Keel length	0.608	17.229	0.521	0.002	<0.001
Breast length	9.236	0.076	0.000	0.84	<0.001
Breast width	3.804	-1.006	-0.003	0.026	0.3
Beak length	43.777	-5.277	-0.028	0.493	<0.001
Beak width	0.013	-5.12	-6.239	-0.135	0.455
Body length	14.287	1.142	0.011	0.357	<0.001
Body circumference	-1.276	-4.076	-0.061	0.001	0.837
White Feather line					
Shank length	41.849	0.667	0.004	0.839	<0.001
Keel length	29.609	0.228	0.001	0.911	<0.001
Breast length	11.6211	0.078	0.000	0.863	<0.001
Breast width	31.305	0.896	0.003	0.746	<0.001
Beak length	42.722	4.623	0.045	0.756	<0.001
Beak width	154.67	2.724	0.000	0.835	<0.001
Body length	54.888	-0.080	0.000	0.855	<0.001
Body circumference	175.032	-12.418	0.000	0.730	<0.001

Additional traits such as beak width ($R^2 = 0.835$), beak length ($R^2 = 0.756$), and body circumference ($R^2 = 0.730$) also contributed substantially to body weight prediction. Even breast width, which showed weak predictive power in the brown line, showed a strong relationship in the white line ($R^2 = 0.746$, $p < 0.001$).

These results suggest a higher degree of morphological consistency and trait integration in the white feather line, with nearly all morphometric measurements strongly and significantly associated with body weight.

The observed differences in predictive power between the two lines may be attributed to genetic variation, differential growth patterns, and conformational uniformity. The brown feather line exhibited selective morphometric influences on body weight, whereas the white line demonstrated broad, uniform correlations across nearly all traits.

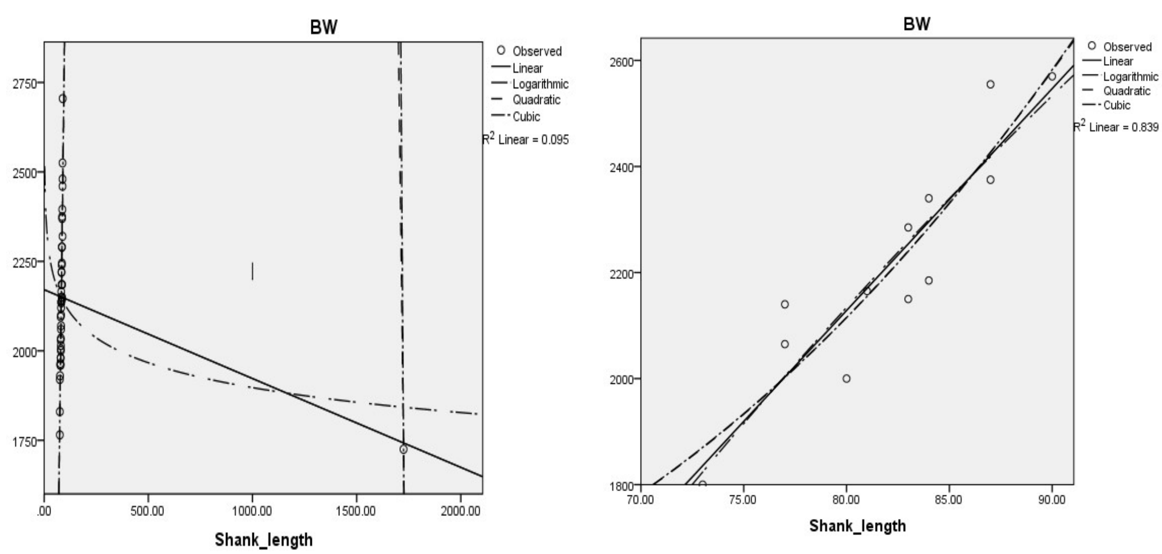
The prominence of keel length in both lines reinforces its biological significance, as this trait reflects the development of the pectoral region, which is highly relevant to muscle mass and body weight. Body length and breast length were also consistently influential, aligning with findings in earlier studies on indigenous poultry breeds.

Musa et al. (2006) reported that body length and keel length were the most predictive traits for body weight in local chickens and ducks. Ajayi and Ejiofor (2009) observed similar results in Nigerian ducks, recommending the use of such measurements in breeding programs. Yakubu et al. (2011) noted that morphometric traits such as keel and breast length are strong predictors of body weight in indigenous poultry. Islam et al. (2018) highlighted keel length and shank length as reliable indicators for early selection in duck breeds.

Conclusions

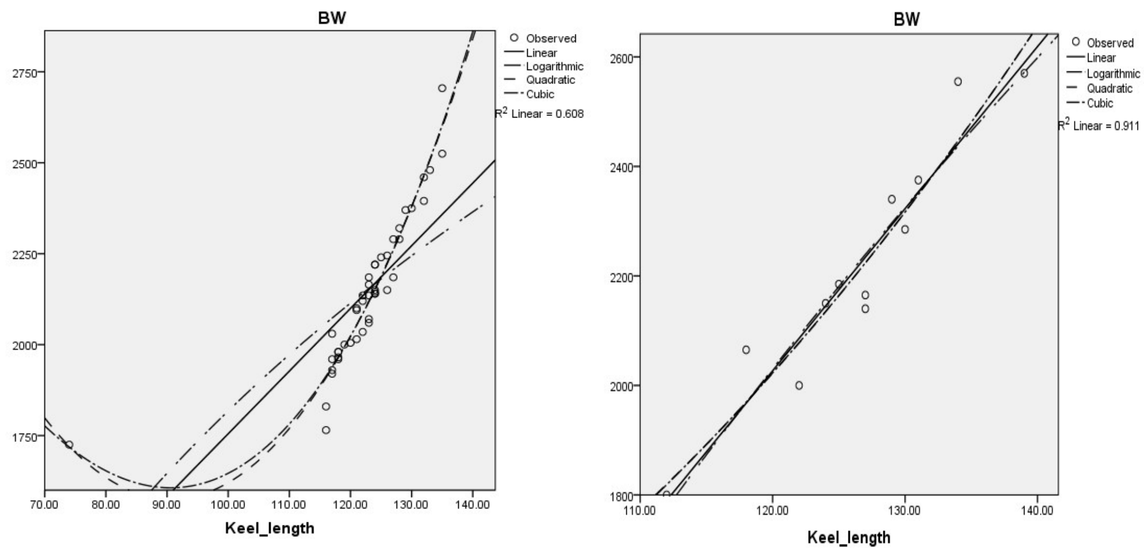
In Breeding Programs, it implicated that feather color can be selected independently of body conformation traits in Domyati ducks. Brown ducks show stronger and more uniform correlations, suggesting they may be more reliable for body weight prediction using morphometrics. White ducks exhibit slightly more variability, possibly indicating different growth or fat deposition patterns. Selection programs can benefit from focusing on high-correlation traits like breast length, keel length, and shank length to improve growth performance.

In brown Domyati ducks, only a few morphometric traits particularly keel length, beak length, and body length serve as meaningful predictors of body weight. In contrast, white Domyati ducks showed significant and strong predictive relationships for all body measurements analyzed. Keel length is the most reliable and consistent trait for predicting body weight in both lines. These findings have practical implications for selection and breeding programs, where such morphometric traits could be utilized to improve growth performance and meat yield in ducks.



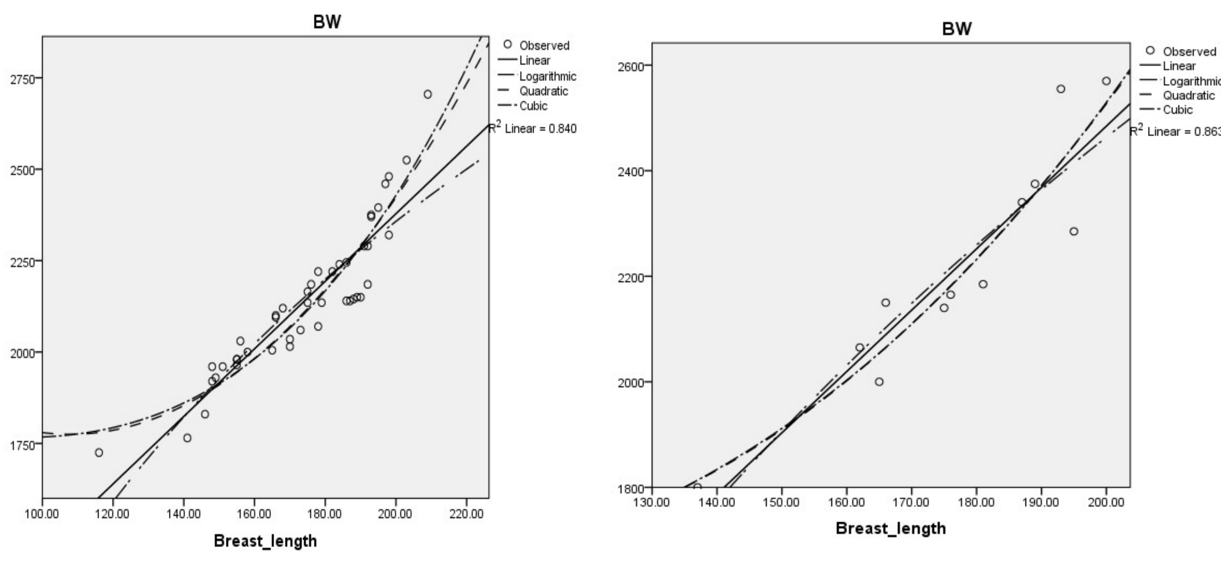
(A) **(B)**

Figure (4): Regression analysis for body weight as dependent factor (Y) and shank length (X) of Brown (A) and White (B) Domyati duck.



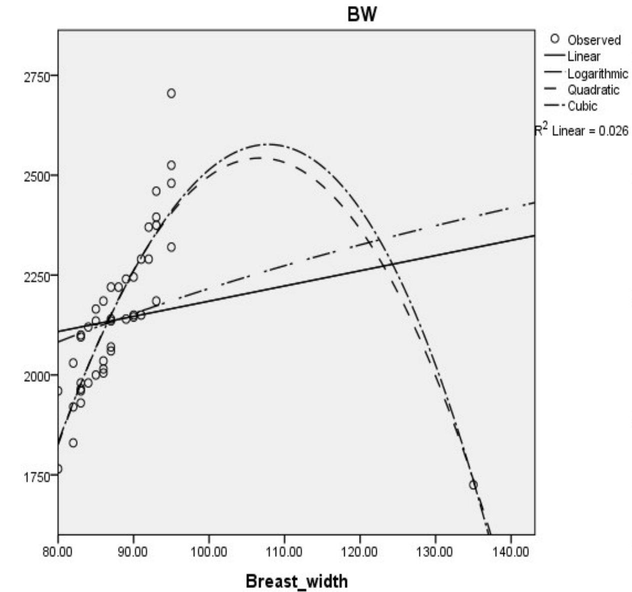
(A) **(B)**

Figure (5): Regression analysis for body weight as dependent factor (Y) and keel length (X) of Brown (A) and White (B) Domyati duck.

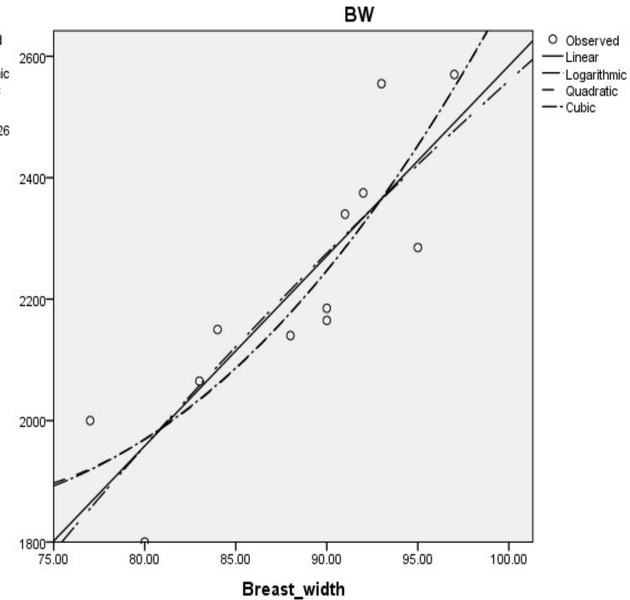


(A) **(B)**

Figure (6): Regression analysis for body weight as dependent factor (Y) and breast length (X) of Brown (A) and White (B) Domyati duck.

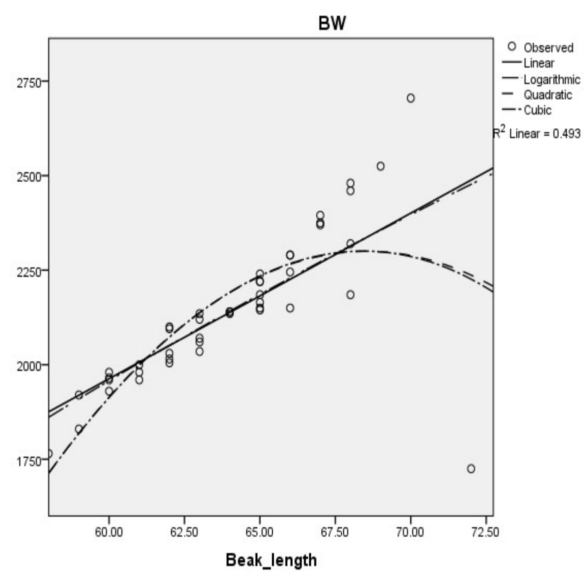


(A)

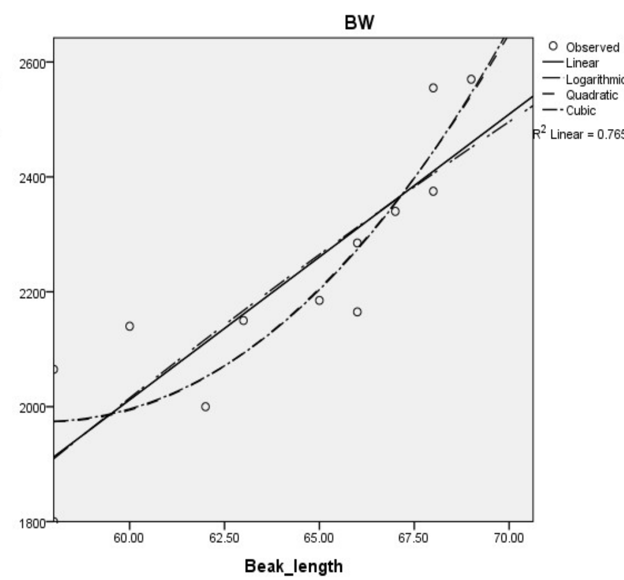


(B)

Figure (7): Regression analysis for body weight as dependent factor (Y) and breast width (X) of Brown (A) and White (B) Domyati duck.

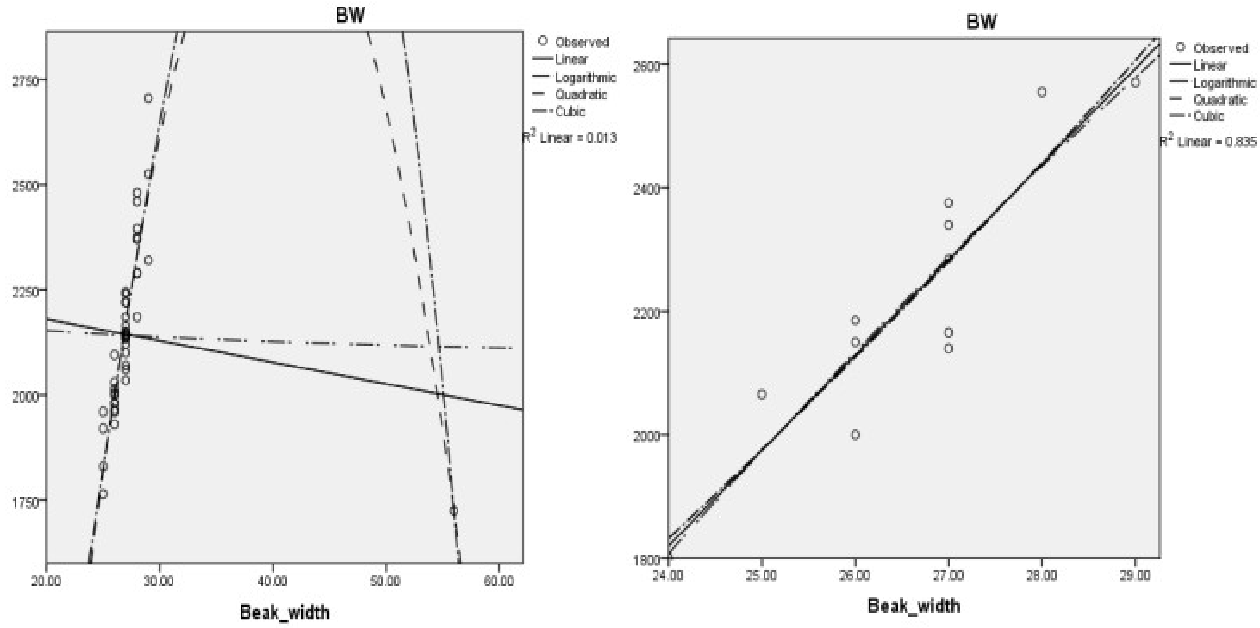


(A)



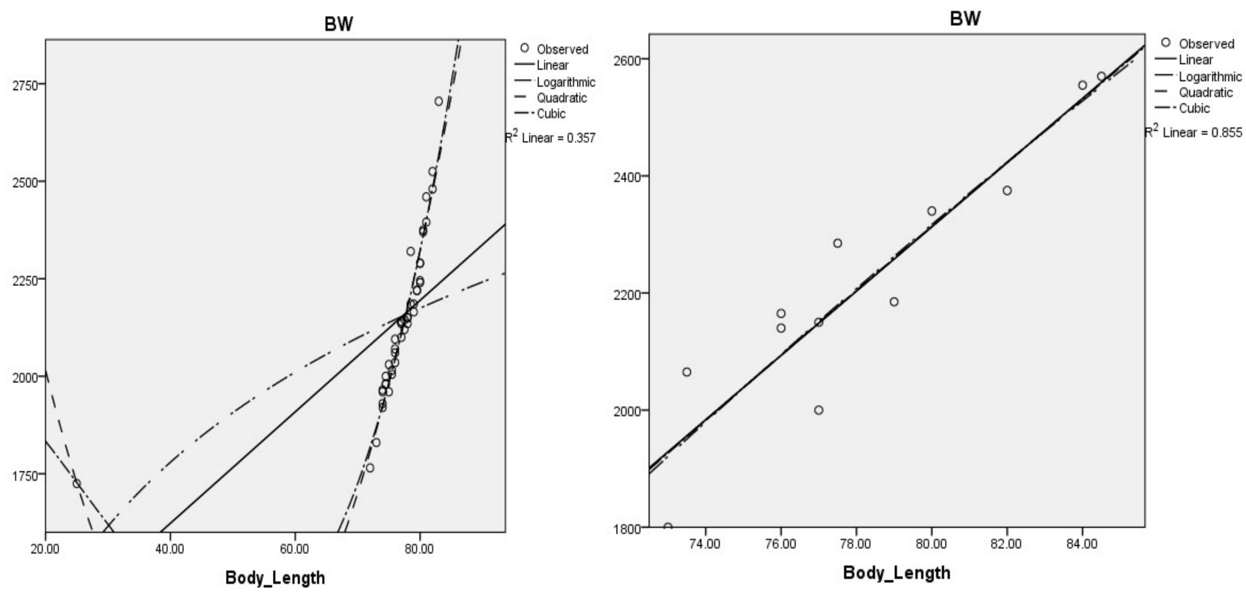
(B)

Figure (8): Regression analysis for body weight as dependent factor (Y) and beak length (X) of Brown (A) and White (B) Domyati duck.



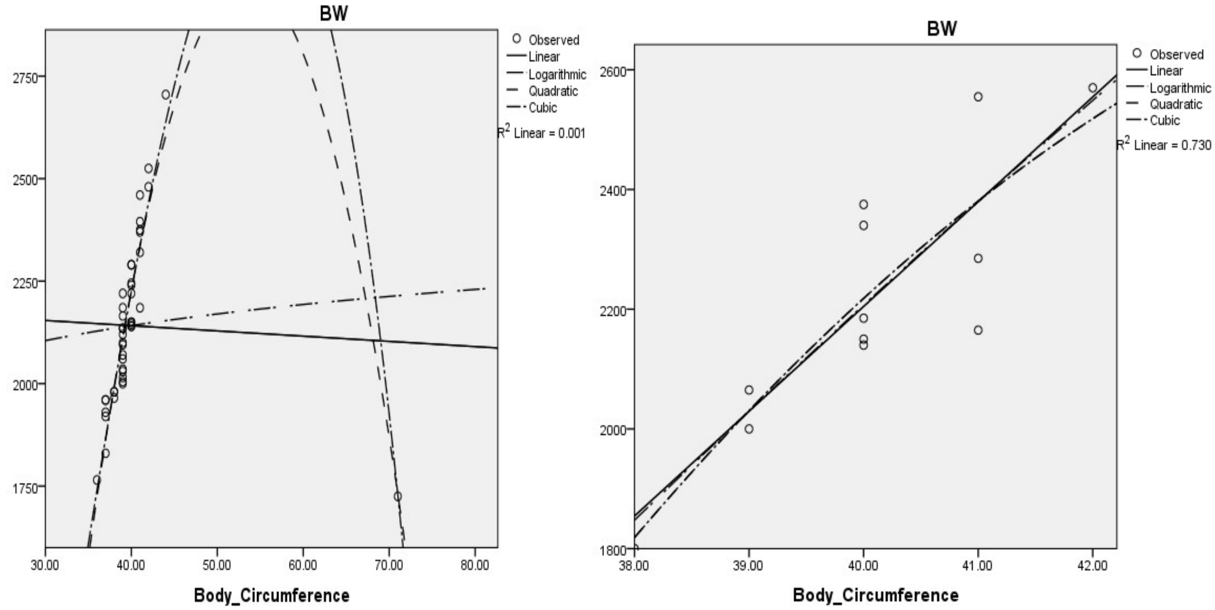
(A) **(B)**

Figure (9): Regression analysis for body weight as dependent factor (Y) and beak width (X) of Brown (A) and White (B) Domyati duck.



(A) **(B)**

Figure (10): Regression analysis for body weight as a dependent factor (Y) and body length (X) of Brown (A) and White (B) Domyati duck.



(A) (B)

Figure (11): Regression analysis for body weight as dependent factor (Y) and body circumference (X) of Brown (A) and White (B) Domyati duck.

References

Abdel-Tawab, M., A. Makram, I. El-Wardaney, A. Zein El-Dien, A.H. El-Attar and A.M. Abdelmoniem (2025). Estimation and analyzing sexual dimorphism for body weight and carcass traits of white and brown Domyati ducks. J. Genet. Environ. Conserv., 13: 22-33. DOI: gercj.com/index.php/gercj/article/view/290/211.

Ajayi, F. O., & Ejiofor, O. (2009). Body weight and linear measurements of mature local chickens and ducks in south-western Nigeria. African Journal of Livestock Extension, 7, 21–26. https://doi.org/10.4314/ajlex.v7i1.51691

Alsaffar, M.A., Makram, A., Rayan, G.N., El-Dien, A.Z., Shehata, W., and El-Attar, A. H. (2024). Effect of beak color on growth performance and carcass characteristics of Pekin ducks. Ind. J. Anim. Res., 58(5), 864-870.10.18805/IJAR.BF-1855

Baldassarre, G. A. (2014). Ducks, geese, and swans of North America (Vol. 1). Johns Hopkins University Press.

Galal, A., Ali, W. A. H., Ahmed, A. M. H., & Ali, K. A. (2011). Performance and carcass characteristics of Dumyati, Muscovy, Peking and Sudani duck breeds. *Egyptian Journal of Animal Production, 48*(2), 191–202.

Guay, P.-J., & Tracey, J. P. (2009). Melanin-based plumage coloration is not associated with measures of physical health in wild waterfowl. J. Avian Biolo., 40(6): 648-655. https://doi.org/10.1111/j.1600-048X.2009.04728.x

Heath, S. E., Devlin, R. H., Pitcher, T. E., & Higgs, D. M. (2020). Rearing environment modulates growth traits in waterfowl: Implications for domestication. Poultry Science,

Ibe, S. N. (1989). Measures of size and conformation in commercial broilers. Journal of Animal Breeding and Genetics, 106(6), 461–469. https://doi.org/10.1111/jbg.1989.106.issue-6

IBM SPSS Corp. (2011). IBM SPSS Statistics for Windows, V. 20.0. Armonk, NY: IBM Corp.

Islam, M.A., Sarker, N.R., & Bhuiyan, A.K.F.H. (2018). Genetic parameters and correlation estimate of body weight and linear body measurements in indigenous duck of Bangladesh. Asian J. Med. Biolo. Res., 4(1): 105-112. doi.org/10.3329/ajmbr.v4i1.36855

Ismoyowati, I.; E. Tugiyanti; M. Mufti and D. Purwantini (2017). Sexual dimorphism and identification of single nucleotide polymorphism of growth hormone gene in Muscovy duck. J. of Ind. Trop. Anim.

Agric., 42(2): 167-174. DOI: 10.14710/jitaa.42.3.167-174.

Kırmızıbayrak, T. and B. K. Boğa (2018). Slaughter and carcass traits of geese with different feather colour and gender. Brazilian Journal of Poultry Science, 20 (4): 759-764. DOI: 10.1590/1806-9061-2018-0766.

Makram, A. (2015). Improving the productive performance of native duck breed by crossing with standard commercial duck breed. PhD. Thesis, Fac. of Agric., Ain Shams Univ., Cairo, Egypt.

Makram, A. (2016). Ducks world (Review Article). The 9th International Poultry Conference (Oral Presentation), 7-10 November, pp. 463-486.

Makram, A., A. A. Galal and A. A. El-Attar (2021). A comparison of three duck strains (Pekin, Muscovy & Sudani) in Egypt for sexual dimorphism with regard to body weight, body measurements and carcass traits. J. Genet. Environ. Conserv., 9 (1): 50-57.

Makram, A., A.H. El-Attar, A. Zein El-Dien, and M. Abdel-Tawab (2024). Impact of clipping tip of tongue on body weight of Pekin duck with short beak and dwarfism syndrome (SBDS). Alnakhla J. Scie., 13 (1): 28-35.

Musa, H. H., Chen, G. H., Cheng, J. H., & Mekki, D. M. (2006). Study on carcass characteristics of chicken breeds raised under the intensive condition. International Journal of Poultry Science, 5(6), 530–533. https://doi.org/10.3923/ijps.2006.530.533

Olsen, R. E., Halverson, N. G., Johnson, K. M., & Williams, C. K. (2021). Morphological adaptations in duck beaks: A comparative study of wild and domestic populations. Avian Research, 12(1), 12. https://doi.org/10.1186/s40657-021-00252-x

RStudio Team (2024). RStudio: Integrated Development for R-Studio, PBC, Boston, MA.

Saatci M.; T. Kirmizibayrak; A.R. Aksoy and M. Tilki (2005). Egg weight, shape index and hatching weight and interrelationships among these traits in native Turkish geese with different colored feathers. Turkish J. of Veterinary and Animal Sciences, 29: 353-357.

Saatci, M.; M. U. A. M. M. E. R.; I. Tilki, Kaya and T. Kirmizibayrak (2009). Effects of fattening length, feather color and sex on some traits in native Turkish geese. II. Carcass traits. Arch. Geflügelk, 73 (1): 61-66.

Sarica, M.; M.A. Bozm and U.S. Yamak (2015). Slaughter and carcass traits of white and multicolor geese reared in backyard in Yozgat. Turkish Journal of Agriculture-Food Science and Technology, 3: 142-147. DOI: 10.24925/turjaf.v3i3.142-147.238.

SAS Institute INC. (2013). SAS/STAT User's Guide, Version 9.4. SAS Inst. Inc., Cary, NC.

Teguia A.; H. Mafouo Ngandjou; H. Defang and J. Tchoumboue (2008). Study of the live body weight and body characteristics of the African Muscovy duck (*Caraina moschata*). Trop. Animal Health & Prod., 40 (1): 5-10. DOI:10.1007/s11250-007-9045-x.

Yakubu S. B. and Ugbo (2011). An assessment of biodiversity in morphological traits of Muscovy ducks in Nigeria using discriminant analysis. International Conference on Biology, Environment and Chemistry, 1: 1-3.

Yakubu, A., Muhammed, M. M., Ari, M. M., Musa-Azara, I. S., & Omeje, J. N. (2015). Correlation and path coefficient analysis of body weight and morphometric traits of two exotic genetic groups of ducks in Nigeria. Bangladesh Journal of Animal Science, 44(1), 1–9. https://doi.org/10.3329/bjas.v44i1.23162

Yakubu, A., Salako, A. E., & Ige, A. O. (2011). Effects of genotype and sex on body weight and morphostructural traits in Nigerian indigenous ducks. Tropical Animal Health and Production, 43(6), 1235–1241. https://doi.org/10.1007/s11250-011-9818-5